Asymmetric price adjustments with the most-favored-customer clause

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SOM-Theme E: Financial markets and institutions

Abstract

In a model of price competition with a most-favored-customer clause we show that cost-change induced price adjustments are asymmetric. That is, the degree of price rigidity differs between increases and decreases. With this policy one would expect firms to be reluctant to decrease prices because of the costs of rebates incurred. Indeed, we show that for some parameter values there is more downward than upward price rigidity. However, it may well be the case that there is more upward rigidity. In particular, this is true for a duopoly where both firms offer the policy. The paper thus gives an alternative explanation for asymmetry in price adjustments.

Keywords: Most-favored-customer clause; Asymmetric price adjustments.

JEL classification: D43; L13.

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1 Introduction

It is well known that prices may be rigid in the sense that cost changes are not immediately and/or fully reflected in prices. This is commonly attributed to the existence of imperfections like adjustment or menu costs. Further, price rigidity can be asymmetric. In that case, there is relatively more downward (or upward) price rigidity. By 'more downward rigidity' we refer to the situation where for a cost change of given size, prices respond faster and/or more when the change is an increase than when it is a decrease. For examples, see Peltzman (2000) and the references therein. Most of the empirical studies of the phenomenon suggest that there is more downward price rigidity. Peltzman (2000) analyzes price rigidities for 77 consumer goods and 165 producer goods. His results show that there is more downward rigidity in more than two of every three markets[1] and he concludes that 'prices rise faster than they fall'. On the other hand there is some evidence of more upward rigidity as well. When Blinder (1994) asked businesspeople in a survey why they would adjust price with a lag after a cost change, they often replied that there was a fear to loose consumers by being the first to raise price. This suggests stronger upward rigidity.

Despite the extensive empirical evidence for asymmetric price adjustments, the theoretical literature on this topic is limited. Several intuitive explanations exist for the phenomenon, though. The first explanation is based on market power, and interprets the 'current' price as a kind of focal price. The idea is that firms may tacitly collude. If there is asymmetric information with respect to firm-specific input prices or demand, tacit collusion may lead to more downward price rigidity. For example, when a firm's own input price rises, the firm will quickly increase its price to show that it keeps to the (unspoken) agreement. On the other hand, when its input price falls, the

[1] For the other markets, Peltzman does not find significant asymmetries.

firm will hesitate to lower its price. Since the other firms do not observe the first firm's input price decrease, they may interpret an output price decrease as a deviation from the agreement. In that case, they will punish the firm for deviating by competing more aggressively.

The second explanation refers to the existence of search costs, which leads to short-term market power. It is often costly (time-consuming) for consumers to search for a lower price offered by a competitor. This gives local monopolists short-run market power. These firms will only have to lower their price after consumers have engaged in the costly search process. Also, if consumers cannot observe the industry-wide cost level but believe it to be volatile, they are not sure whether a higher price reflects higher costs or a higher price relative to competitors. The benefits of search are reduced. Again, this gives firms short-run market power and allows them to keep the price at the old, higher level for some time after a cost decrease.

Third, adjustment or menu costs may also explain asymmetric price adjustments. Adjustment costs may be asymmetric themselves and depend on the sign of the price change, for example in case of inflation. However, even symmetric adjustment costs may result in more downward rigidity. This reasoning refers to changes in input prices that are caused by supply shocks of inputs. If there are no stocks, a negative supply shock of inputs unavoidably results in a lower output for the entire sector, implying a price increase. A positive input supply shock, however, does not necessarily lead to higher output and a lower price. In the latter situation, if the adjustment costs exceed the incremental profits from the higher output, the firms will choose not to adjust their output levels.

Hannan and Berger (1991) present a simple theoretical framework that allows for asymmetric price adjustments in their discussion of price rigidity for deposit interest rates. In this framework, the gain from adjusting the deposit rate after a change in the security rate depends on the slope of the deposit supply curve as perceived by the bank. The incentive to adjust the deposit rate therefore depends on this slope as well as on the menu cost, both of which are allowed to differ between price increases and decreases. Asymmetric price adjustments are thus explained by asymmetries in the parameters of the model.

A more elaborate model is presented by Damania and Yang (1998). They formalize the first argument given above and show that in an infinitely repeated oligopoly with imperfect information, prices may be more rigid downward than upward. In a price-setting duopoly with differentiated goods they let firm-specific demand fluctuate randomly. Firms are assumed to know their own state of demand but not that of the competitor. Damania and Yang show that there exist circumstances in which price increases occur more frequently than price decreases. Deviations from the collusive price cannot be detected with certainty because of the asymmetric information. So, when a firm charges the low collusive price (which corresponds to the low demand state), this may either be because of its low demand state or because it defects. Therefore, the firms must punish with some probability when the competitor sets a low collusive price. For some parameter values, it turns out that firms choose to forgo the price reduction when demand is low in order to avoid the punishment.

The present paper provides a theoretical model that may explain asymmetric price adjustments. It is based on the most-favored-customer clause. With this clause a firm guarantees its current customers that if it will charge a lower price in the future (up to some specified date), they will be reimbursed the difference. Firms may choose to offer this clause because it allows them to commit to a higher price, which increases their profits. The policy will be explained in more detail in the next section. Note that the mfc clause can be interpreted as a kind of self-imposed, asymmetric menu cost: if the firm decreases its price it will have to pay some endogenous amount of money.

Intuitively, firms using this policy will be reluctant to decrease their price because of the costs of rebates incurred. This would suggest more downward rigidity. We show that this indeed may occur for some parameter values. Surprisingly, however, there also exist cases in which the policy leads to the opposite result, that is, to more upward rigidity. In particular, this occurs when two duopolist firms both offer the policy.

The intuition behind this result comes from the fact that in a duopoly equilibrium prices are determined by the interaction of the two firms' price-setting behavior. Furthermore, the equilibrium price changes we refer to in the above are cost-change induced, not unilateral responses to price changes by the competitor. Indeed, if costs do not change but a competitor reduces its price, a firm offering the clause will unilaterally choose to keep its price constant because of the cost of rebates otherwise incurred (if the price reduction by the competitor is not too large). This is reflected in the shape of the reaction curves. However, equilibrium prices are determined by the intersection of the reaction curves of the two firms, and if costs change these reaction curves shift. So the response of equilibrium prices to a cost change is described by the difference between the intersections of the old reaction curves and the new reaction curves, respectively. Even though a firm is unilaterally reluctant to decrease its price when the other firm does so, this does not necessarily imply that prices are more rigid downward after a cost change. This paper thus provides an alternative explanation for asymmetric price adjustments, where the asymmetry may either refer to more upward or more downward rigidity.

The remainder of this paper is structured as follows. In the next section we elaborate on the most-favored-customer clause. In section 3 we graphically analyze the effects of a cost change in a duopoly where one or both firms offer the policy. Although the main results will carry over to the case of three or more firms, we focus on the duopoly case for expositional convenience.

We show that there may be asymmetric price adjustments following a cost change, and show that this may result in either more upward rigidity or more downward rigidity. In section 4 we illustrate our argument with a simple linear model of price competition with heterogeneous goods. Depending on the values of the parameters, there will be either more upward or more downward rigidity. We also show formally that, in this specific model, the policy will indeed be offered by at least one firm in equilibrium. Section 5 concludes.

2 The most-favored-customer clause

With the most-favored-customer (mfc) clause, a firm guarantees its current customers that if it will charge a lower price in the future - up to some specified date - they will be reimbursed the difference. Cooper (1986) has analyzed the effects of this policy on competition and prices. He argues that in a model of price competition among two firms producing heterogeneous goods, it may be beneficial to a firm if it can somehow commit to charge a minimum price above the Bertrand equilibrium price (Cooper, 1986, p. 381). By doing so the firm can earn at most the profits that a Stackelberg leader would earn. The competing firm benefits from this commitment as well, because it reduces competition. Cooper shows that the mfc policy as described above effectively enables the firm offering the policy to commit to such a minimum price, softening price competition. Examples include the mfc policies offered by two manufacturers of turbine generators from the early 1960s to the mid 1970s (see Cooper, 1986, pp. 385-386), in the pharmaceutical industry (Scott Morton, 1997), and in long-term natural gas contracts (Crocker and Lyon, 1994).

Cooper (1986) suggests several reasons why the mfc clause may be difficult to implement. He mentions the costs of maintaining records of customers and communicating price changes. The above references indicate that they do occur, however. Furthermore, we believe the policy to be more general than this argument suggests, for two reasons.

First, imagine buying an expensive durable good, say a new tv set, at your local store. If you notice shortly after the transaction that the price of this particular tv set has declined dramatically, you may well step in and ask for a rebate. In fact, the store owner may even give you some rebate, out of fear to loose you as a future customer or to damage his reputation. This type of implicit mfc policy may be widespread.

Second, we believe that the policy applies to various markets in which consumers can invite offers by suppliers. An example is the Dutch mortgage market.[2] In The Netherlands, most mortgages are fixed rate contracts. If a person wants to buy a house with a fixed rate mortgage, he (or she) can invite mortgage offers from one or more banks. The bank(s) will provide an offer to the client, stating that he can borrow at most this or that amount at some fixed rate. The offer is valid for a period of, say, one month. The client can accept it at any time during this period and get a mortgage at the given rate; if the client wants to obtain a mortgage from the bank after the offer has expired, he has to solicit for a new offer. The crucial idea in this argument is that whenever the mortgage rate increases, the current offers keep the old, low rate. If clients accept their offer after the increase, they will pay the low rate even though the current mortgage rate is higher. However, when the mortgage rate decreases, the bank cannot charge the old, high rate to clients that have a non-expired offer at the old rate (they would simply ask for a new offer at the current, low rate if the bank would do so). So, a mortgage rate increase does not affect current offers, whereas

[2] Jacobs and Toolsema (2001) and Toolsema and Jacobs (2001) analyze asymmetric price adjustments in this market. They conclude that the Dutch mortgage rate is more rigid downward.

a decrease does. The offer resembles an option to obtain a mortgage at the specified rate.

This type of offer policy is strikingly similar to the mfc clause. In fact, mortgage offers as described above can be interpreted as a special kind of mfc clause. For those clients who do indeed accept the offer and get a mortgage from the bank, everything is as if they already decided to accept when they invited the offer, combined with an mfc clause that guarantees them the lowest mortgage interest rate offered by the bank in the 'future', i.e. the month in between the invitation and the expiration of the offer. A similar argument holds for other products and services for which consumers can invite this kind of option-like offers.

3 The effects of a cost change with the mfc clause

Consider the following three-stage model of price competition with differentiated goods and an mfc policy (based on Cooper, 1986). There are two firms, A and B, that face identical cost and demand conditions. In the first stage of the model, say at time zero, the firms decide whether or not to offer the mfc policy. Given their choices, the next two stages of the model are a competition subgame in which firms compete for two periods. In these periods 1 and 2, they compete by setting prices. However, if at time zero they have chosen to offer the mfc policy and set a second-period price below their first-period price, they have to reimburse the difference to their first-period customers. Additionally, we assume that after the first competition period the firms' marginal costs change, and we analyze the response of equilibrium prices to this cost change. Although it is usually not true in the real world, we assume for simplicity that all first-period consumers claim their refund. If this is not true and only a part of the total rebate is claimed, the effects derived below will be weaker but qualitatively similar. We choose to abstract from this complicating factor and thus do not model consumer behavior explicitly.

Consider the second period of the competition subgame. The solid lines in Figure 1 show the second-period reaction functions of the firms in the case where only firm A has decided to offer the mfc policy, *without* a cost change. For now, we ignore the cost change and focus on the shape of firm A's reaction curve in the presence of an mfc clause and the resulting equilibrium prices. The second-period prices of firms A and B are denoted by p^A and p^B, respectively. Firm B's reaction curve $p^B\left(p^A\right)$ is simply the standard reaction curve because it is assumed not to offer an mfc clause. Suppose firm A charged the price p_1^A in the first period. Firm A's second-period reaction function $p^A\left(p^B\right)$ equals the standard reaction function for any price *above* the first-period price p_1^A. However, with the mfc policy firm A's second-period reaction function shifts outward for any price below its first-period price because of the costs of rebates. Thus, as soon as firm A's reaction function hits p_1^A, at point F in the figure, $p^A\left(p^B\right)$ becomes vertical. For these levels of p^B the rebates to first-period customers outweigh the benefits of reducing price below p_1^A. However, as firm B's price becomes extremely low, say below the level indicated by point D in the figure, firm A will set a second-period price below p_1^A even though it has to rebate the difference to its first-period customers. In that case, the positive effect on profits of charging a lower price and getting a greater share of the market dominates the negative effect of the rebate. Firm A's second-period reaction curve thus has a flat segment at firm A's first-period price, the length of which is positively related to the firm's first-period sales (which indicates the number of customers that can claim a refund in the second period). Point E denotes the resulting equilibrium. Note that in equilibrium both firms charge a price above the Bertrand equilibrium price, which is indicated by **B** in Figure 1). We focus on the case where the reaction curves intersect in the flat segment of firm A's reaction curve. Alternatively, there could be an equilibrium where the intersection is in the lower segment of that curve.

The flat segment of the reaction curve suggests that a firm offering an mfc policy is reluctant to lower its price. However, when discussing asymmetries in price adjustments, we concentrate on price adjustments following a cost change. This refers to a *shift* of the reaction curves. Since the firms are assumed to face identical cost and demand conditions, we focus on an industry-wide cost change, which is the same for both firms. In general, we refer to a (constant) marginal cost c, that changes to the new level $c + \Delta c$. Our solution strategy is as follows. For now, we treat the cost change as unexpected, and derive the reaction curves and equilibrium prices. Later, in the discussion of the formal model, we argue that if the firms know the ex ante probability distribution of the cost change Δc, the outcomes are exactly the same as for an unexpected cost change (for the particular type of distribution used). Finally, we show that the mfc clause will indeed be offered in equilibrium.

In Figure 1 the dashed lines illustrate the effects of a small unexpected cost increase in the second competition period. The general effect of such a cost increase is to shift reaction functions outward in the direction of the arrows. Firm A's reaction curve remains vertical at p_1^A, as shown in the figure. For the particular cost change described in the figure, we see that firm A will continue to charge the old equilibrium price p_1^A, whereas firm B will set a higher price. However, had the line segment EF been shorter (or the cost increase larger), firm A might have increased its price as well, and in that case the increase for firm B would have been larger (in an absolute as well as in a relative sense).

Similarly, Figure 2 describes the effects of a cost decrease of the same size. The dashed lines illustrate the second-period reaction curves after the cost decrease. The general effect of such a cost decrease is to shift reaction

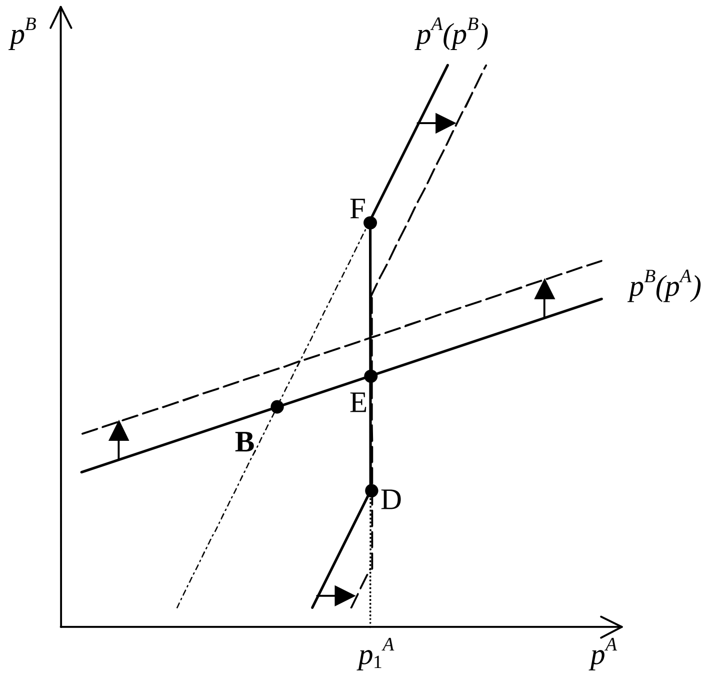

Figure 1: Reaction functions of firms A and B when only firm A offers the mfc policy: the effects of a cost increase.

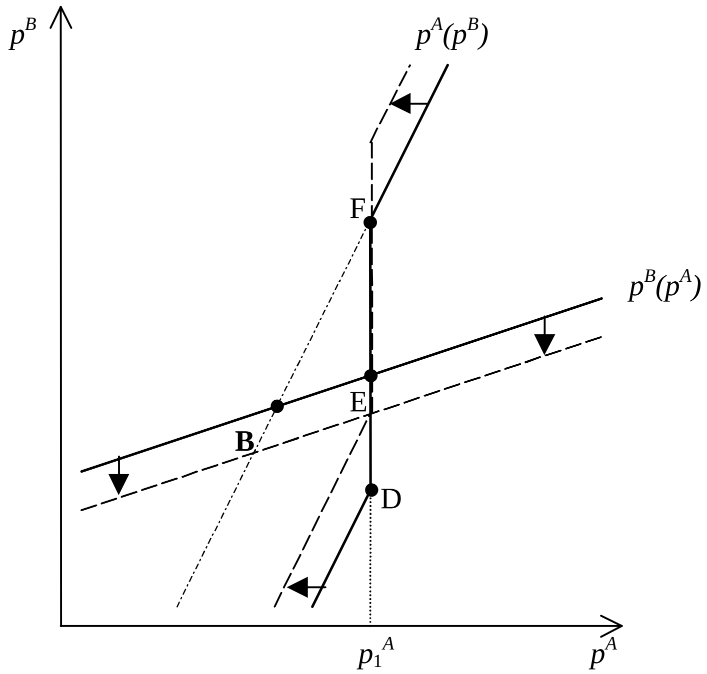

Figure 2: Reaction functions of firms A and B when only firm A offers the mfc policy: the effects of a cost decrease.

functions inward. Firm A's reaction curve will again remain vertical at p_1^A, as shown in the figure. For the particular cost change described in the figure, we see that firm A will just continue to charge the old equilibrium price, whereas firm B will set a lower price. However, had the line segment DE been slightly shorter (or the cost decrease slightly larger), firm A would have decreased its price as well, and for firm B the price decrease would have been larger (in an absolute as well as in a relative sense).

In the particular example in Figures 1 and 2, there is more upward rigidity. Since the line segment EF is longer than the line segment DE, prices are more rigid upward than downward. For a cost change of given size, firm B will always adjust its price. Firm A will not adjust its price for small cost changes; it will decrease price for intermediate cost decreases but not increase price for corresponding cost increases; and it will adjust its price for large cost changes in either direction. Furthermore, the price change by firm B will be relatively small for the cases in which firm A does not adjust its price. Alternatively, if the line segment DE is longer than the line segment EF, there will be more downward rigidity. Note that the length of DE and EF together is determined by the size of the rebate to first-period consumers, and the relative lengths of the two segment are determined by the point at which firm B's reaction curve intersects the flat segment. Thus, for example, if the rebate is relatively large, and firm B response to firm A's first-period price (as determined by B's reaction curve) is relatively high, the segment DE is relatively long, which may imply more downward rigidity.

Now consider the situation in which both firms have decided to offer the mfc policy, see Figure 3. Equilibrium prices are now determined by the simultaneous maximization by the firms of the following expression:

$$\Pi_2^i + \left(\min\{p_2^i - p_1^i, 0\}\right) q_1^i$$

where Π_2^i refers to second-period profits, p_t^i to period-t price ($t = 1, 2$), and

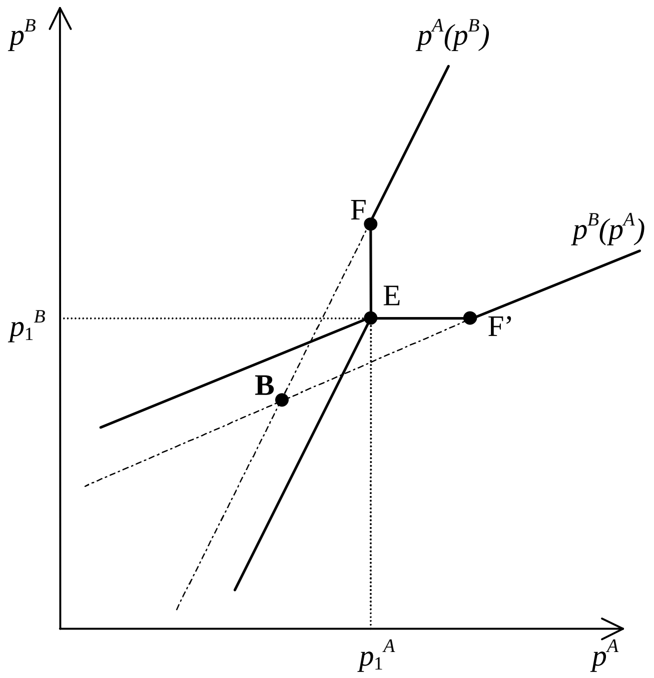

Figure 3: Reaction functions of firms A and B when both offer the mfc policy.

q_1^i to first-period quantity sold by firm $i = A, B$. Using backward induction, this is the maximization problem for the second stage of the model. Knowing this, and the resulting equilibrium price, the firm will choose to set this same price in the first period. Note that the profit function Π_2^i depends on the cost and demand conditions, as well as on the price set by the other firm. The relevant first-order conditions are

$$\frac{\partial \Pi^i}{\partial p^i} + q^i = 0. \tag{1}$$

These conditions determine equilibrium prices. Note that in Figure 3, the equilibrium E coincides with the lower ends of the flat segments of the reaction curves (illustrated by D in Figures 1 and 2). The reason for this is that the condition (1) for $i = 1, 2$ does not only describe the equilibrium E, but also the reaction functions of firms $i = 1, 2$ with the rebate to first-period customers, that is, the lower parts of the kinked reaction curves in Figure 3. Thus, the equilibrium E and thus equilibrium prices, indicated by p_1^i in the figure, are determined by the intersection of the lower parts of the reaction functions. As a result, there can be no flat segment in the reaction curves below E. Above the equilibrium prices, there are no rebates and the relevant reaction functions are again the standard reaction functions $p^i\left(p^j\right)$, $i, j = A, B$, $i \neq j$. From Figure 3 it can be seen that a cost decrease will inevitably lead to lower prices charged by the firms. Only in case of a cost increase prices may be sticky. In this situation, there is more upward rigidity. However, note also that *if* the cost increase is large enough for prices to adjust, they will adjust to the (new) Bertrand price level, whereas after a cost decrease, prices will always remain above the new Bertrand level.

This simple graphical analysis makes clear that whenever both firms offer the mfc policy in equilibrium there will be relatively more upward rigidity in price adjustments. If only one firm offers the policy in equilibrium, there can be either more upward rigidity or more downward rigidity. The precise effect depends on the parameters of the model. Note that the policy choices of the firms in the pre-competition stage, period zero, themselves depend on the parameters as well. In the next section we present a simple model to illustrate these results.

4 A simple linear model

Below we present a simple linear model to formally describe the effects of cost changes in the presence of the mfc clause. Again, we use the setup in which firms have to choose at time zero whether or not to offer the mfc clause, followed by a competition subgame in which firms compete in prices for two periods. We use a standard model of price competition with heterogeneous goods to model the competition subgame explicitly. After discussing the model and deriving the equilibrium prices, we introduce an ex ante probability distribution for the cost change. Knowledge of this distribution does not affect the firms' behavior. Thus, equilibrium prices are not affected.[3] Finally, we derive the subgame-perfect Nash equilibrium of the game and show that the mfc policy will indeed be offered by at least one firm.

4.1 A simple model of price setting with product differentiation

Our framework is based on a simple one-period model of price competition with product differentiation. There are two firms, $i = A, B$, producing heterogeneous goods, with inverse demand for each firm given by

$$\begin{aligned} p^A &= a - bq^A - \theta b q^B, \\ p^B &= a - bq^B - \theta b q^A. \end{aligned}$$

The parameter $\theta \in (0,1)$ indicates the degree of product differentiation. If θ is close to zero, products are highly differentiated, whereas for θ close to one products are relatively homogeneous. In direct form, demand can be written as

$$\begin{aligned} q^A &= \frac{a}{b(1+\theta)} + \frac{\theta}{b}\frac{p^B}{1-\theta^2} - \frac{1}{b}\frac{p^A}{1-\theta^2}, \\ q^B &= \frac{a}{b(1+\theta)} + \frac{\theta}{b}\frac{p^A}{1-\theta^2} - \frac{1}{b}\frac{p^B}{1-\theta^2}. \end{aligned}$$

[3] Since the probability distribution chosen below does not affect the equilibrium of the model, we might continue to focus on the effects of an unexpected cost change. However, if it is possible for costs to change in the future, firms will in general take this possibility into account when making decisions in earlier stages about the mfc policy and first-period prices. Therefore, we allow for an ex ante probability distribution and show that this does not affect the results.

Let $c < a$ denote the constant marginal cost. Firm i's maximization problem is given by

$$\max_{p^i} \quad \Pi^i = \left(p^i - c\right) q^i.$$

The standard reaction functions are given by

$$\begin{aligned} p^A &= \frac{1}{2}c + \frac{1}{2}\left(1-\theta\right)a + \frac{1}{2}\theta p^B, \\ p^B &= \frac{1}{2}c + \frac{1}{2}\left(1-\theta\right)a + \frac{1}{2}\theta p^A. \end{aligned} \tag{2}$$

Solving for prices, in equilibrium we have

$$p^A = p^B = \widetilde{p} = c + \frac{1-\theta}{2-\theta}\left(a-c\right) \tag{3}$$

and equilibrium quantities are

$$q^A = q^B = \widetilde{q} = \frac{a-c}{b\left(1+\theta\right)\left(2-\theta\right)},$$

where we use a tilde to refer to the Bertrand equilibrium value of a variable.

We use this model in a simple game to illustrate the occurrence of asymmetric price adjustments with an mfc clause. Consider again the above setup in which, at time zero, firms decide whether or not to offer the mfc clause. The choice is indicated by the policy variable M^i which takes on the value 1 if firm i adopts the policy, and the value 0 otherwise. $M = (M^A, M^B)$ represents the policy choices of the two firms. In periods 1 and 2 the firms set prices, and if a firm offers the clause and sets second-period price below first-period price, it has to rebate the difference to its first-period customers. We analyze the effects on prices of a cost change at the beginning of the second period. Below, we first discuss the price-setting behavior of the firms in the competition subgame (periods 1 and 2). We do so for the various possible policy choices M, skipping the case $M = (0, 1)$ because it is symmetrical to that of $M = (1, 0)$. Then we turn to the policy choice itself, allowing the firms to know the ex ante probability distribution of the cost change, and we determine the subgame-perfect Nash equilibrium of the game.

4.2 No firm offers the mfc clause: $M = (0, 0)$

If no firm offers the mfc policy, periods 1 and 2 are simply repetitions of the benchmark model. Then, the equilibrium of the competition subgame is the same as that of the standard single-period model derived above. The firms charge the Bertrand prices $\widetilde{p}$ from (3) in each period. The effects of a cost change in the second period are straightforward as well. Second-period equilibrium prices are simply determined by (3), substituting the new cost level.

4.3 Only firm A offers the mfc clause: $M = (1, 0)$

As in the previous section, we focus on the equilibrium in which the reaction curves intersect in the flat segment of A's reaction curve.[4] Using backward induction, we should start solving the second period. Knowing that firm A offers the mfc policy and assuming for now that marginal cost equals c, firm B realizes that firm A will charge the same price in period 2 as it charged in period 1 (otherwise, firm A would not have offered the mfc policy in the first place). Therefore, in period 2 firm B behaves as a follower. It maximizes its profits, taking the price of firm A as given. This implies that for firm B in the second period we have the standard reaction function from (2). In the first period, firm A realizes that firm B behaves in this way, and that A itself will charge the same price in the second period as it did in the first. Therefore, it sets a price p^A that maximizes total profits $\Pi_1^A + \Pi_2^A$ substituting the reaction function of firm B in second stage profits Π_2^A. For a maximum, we take the derivative with respect to firm A's price p^A and set it equal to zero. This is the FOC for firm A. In the first period, firm B will also behave according to the standard reaction function from (2).

[4] The other equilibrium, where the intersection is in the lower part of A's reaction curve (the part with the rebate) turns out to be irrelevant in the current simple model.

Combining, we find that firm A's equilibrium price in each period is given by

$$p^{A*} = c + \frac{2(1-\theta)(2+\theta)}{8-3\theta^2}(a-c) \tag{4}$$

and firm B's equilibrium price is given by

$$p^{B*} = c + \frac{(1-\theta)\left(8+4\theta-\theta^2\right)}{2\left(8-3\theta^2\right)}(a-c). \tag{5}$$

We use the superscript * to refer to equilibrium prices. Note that $0 < \theta < 1$ implies $p^{A*} > p^{B*} > \widetilde{p}$. In equilibrium, firm A charges a higher price than firm B does, and both equilibrium prices are above the Bertrand price.

Returning to the graphical representation (compare Figures 1 and 2), firm A's second-period reaction function equals the standard reaction function from (2) to the right of p^{A*}, and is vertical for p^B below $\overline{p^B}$ (indicated by F in the figures). This number $\overline{p^B}$ is the value of p^B for which the standard reaction curve equals $p^A = p^{A*}$. So, for high values of p^B, firm A would like to set a price greater than or equal to its first-period price, and there is no rebate involved. Therefore, firm A's reaction function is described by the standard reaction function. However, as soon firm A would consider charging a price below p^{A*} if there were no rebate involved, which happens as p^B falls below $\overline{p^B}$, firm A must take the rebate to first-period customers into account. This implies that as p^B falls below $\overline{p^B}$, firm A's reaction function becomes flat and it will continue to charge p^{A*}. The price $\overline{p^B}$ is determined by setting firm A's standard reaction function equal to p^{A*}, giving

$$\overline{p^B} = c + \frac{(1-\theta)(4+3\theta)}{8-3\theta^2}(a-c) > p^{B*}. \tag{6}$$

For very low p^B, it may be optimal for firm A to lower its price below p^{A*} and incur the costs of the rebate. Then, firm A's second-period reaction function is only vertical until the point where it reaches $p^B = \underline{p^B}$. The number $\underline{p^B}$ is the value of p^B where the alternative reaction function, with the rebate, equals $p^A = p^{A*}$. This alternative reaction function describes the price firm A would choose to set if firm B charges a certain price p^B and firm A has incur the rebate. Given the first-period equilibrium price p^{A*}, the reaction function with is determined by the maximization problem

$$\max_{p^A} \quad \Pi^A + \min\{p^A - p^{A*}, 0\}q\left(p^{A*}\right).$$

The corresponding FOC is

$$\frac{\partial \Pi^A}{\partial p^A} + q\left(p^{A*}\right) = 0.$$

This can be solved for p^A to give the reaction function

$$p^A = \frac{1}{2}c + \frac{1}{2}(1-\theta)a + \frac{1}{2}\theta p^B + \frac{1}{4}\frac{(1-\theta)(2-\theta)(\theta+2)^2}{8-3\theta^2}(a-c). \tag{7}$$

This is the reaction function with the rebate for firm A. Note that it has the same slope $\frac{\theta}{2}$ as the standard reaction function. The price $\underline{p^B}$ can be calculated in two ways. The first approach is to calculate the difference between the reaction function between the rebate and the standard reaction function. The difference between $\overline{p^B}$ and $\underline{p^B}$ is equal to this expression times the inverse of the slope of the reaction function, $\frac{2}{\theta}$. The second approach is simply to calculate the price of firm B for which firm A's reaction function with rebate hits p^{A*}. We find

$$\underline{p^B} = c + \frac{(1-\theta)\left(\theta^3 + 8\theta^2 + 4\theta - 8\right)}{2\theta\left(8-3\theta^2\right)}(a-c). \tag{8}$$

(Note that if $\theta < 0.754$, we have $\underline{p^B} < c$. Firm B then earns negative profits if it charges $\underline{p^B}$.)

Now let us turn to the effects of a cost change in period 2. The derivative of the standard reaction functions (2) with respect to c is given by $\frac{1}{2}$. If the marginal cost c changes by Δc with $|\Delta c| = \delta$, $\delta < a - c$, the reaction function shifts by an amount of $\frac{1}{2}\delta$ (in the direction of the arrows in Figure 1 or 2). The size of the shift is independent of the sign of the cost change. The reaction function with the rebate (7) after the cost change becomes[5]

$$p^A = \frac{1}{2}c + \frac{1}{2}\delta + \frac{1}{2}(1-\theta)a + \frac{1}{2}\theta p^B + \frac{1}{4}\frac{(1-\theta)(2-\theta)(\theta+2)^2}{8-3\theta^2}(a-c). \quad (9)$$

So, this reaction function also shifts by an amount of $\frac{1}{2}\delta$ (in the direction of the arrows in Figure 1 or 2). Again, the size of the shift is independent of the sign of the cost change. Therefore, in order to determine whether there is more upward or downward rigidity, we can simply compare the lengths of EF and DE in Figures 1 and 2, as suggested earlier. This gives the following result.

Proposition 1 *In the case of $M = (1, 0)$, where only one firm offers the mfc clause, there is always more downward rigidity in price adjustments due to cost changes in this particular model.*

Proof. After a cost change, the upper parts of $p^A\left(p^B\right)$ and $p^B\left(p^A\right)$ shift by an amount of $\frac{1}{2}\delta$ in the direction of the arrows in Figures 1 and 2. In vertical direction, this implies shifts of $\frac{2}{\theta}\frac{1}{2}\delta = \frac{\delta}{\theta}$ and $\frac{1}{2}\delta$, respectively. The lower part of $p^A\left(p^B\right)$ also shifts by an amount of $\frac{2}{\theta}\frac{1}{2}\delta = \frac{\delta}{\theta}$ in vertical direction. Observing that the length of EF is given by $\overline{p^B} - p^{B*}$ and the length of DE is given by $p^{B*} - \underline{p^B}$, this implies that the condition for more downward rigidity in price adjustment is

$$\overline{p^B} - p^{B*} - \frac{\delta}{\theta} < p^{B*} - \underline{p^B} - \frac{\delta}{\theta}.$$

Substituting, this condition can be rewritten in terms of the parameters of

[5] Note that this reaction function comes from the FOC $\frac{\partial \Pi^A}{\partial p^A} + q\left(p^{A*}\right) = 0$. When the cost changes in the second period, this only affects the first term (not the second). Therefore, we cannot simply replace c by $c + \Delta c$ in the reaction function derived above.

the model as

$$-\frac{1}{2}(1-\theta)(2+\theta)\frac{(a-c)\left(4-3\theta^2\right)}{\left(8-3\theta^2\right)\theta}<0.$$

This condition is satisfied for any $\theta \in (0,1)$. That is, in this model, for the case of $M=(1,0)$, there is always more downward rigidity in price adjustments following to cost changes. ■

4.4 Both firms offer the mfc clause: $M=(1,1)$

In the case $M=(1,1)$, optimal prices satisfy

$$\frac{\partial \Pi^i}{\partial p^i}+q^i=0 \qquad i=A,B.$$

Solving these conditions for prices, we find

$$p^{A*}=p^{B*}=c+\frac{2(1-\theta)}{3-2\theta}(a-c) \tag{10}$$

Returning to the graphical representation (compare Figure 3), the reaction functions of firm A and B are given by the standard reaction functions above the prices $\overline{p^B}$ and $\overline{p^A}$ where they hit p^{A*} and p^{B*}, respectively. These prices are given by

$$\overline{p^A}=\overline{p^B}=c+\frac{(1+2\theta)(1-\theta)}{(3-2\theta)\theta}(a-c)>p^{A*}=p^{B*}. \tag{11}$$

Firm A (B)'s second-period reaction function is vertical (horizontal) up till the point $\underline{p^B}$ $(\underline{p^A})$ where the alternative reaction function, with a rebate, hits p^{A*} (p^{B*}). These reaction functions are determined by the very same FOCs that determine equilibrium prices. Note that substituting first-period prices $p^{A*}=p^{B*}$ in q^i and setting the resulting reaction functions equal to p^{A*} and p^{B*}, respectively, will result in $\underline{p^B}=p^{B*}$ and $\underline{p^A}=p^{A*}$, precisely because these are the FOCs that determine p^{A*} and p^{B*}.

With respect to price adjustments following cost changes this implies that for $M = (1, 1)$, whenever $\Delta c < 0$, prices will decrease since the reaction curves are not flat *below* the equilibrium price charged (compare Figure 3). Note that prices will remain above the Bertrand price level. In case of a cost increase the effect depends on the size of $\Delta c = \delta$. If the shift of the upper (standard) parts of the reaction functions along EF (EF') is less than the length of EF (EF'), $\overline{p^B} - p^{B*} = \overline{p^A} - p^{A*}$, prices will remain at the first-period level. If δ is large, however, prices will increase and they will equal the Bertrand prices corresponding to the new cost level. Summarizing, in this case, firms always adjust prices downward following a cost decrease whereas they are reluctant to increase prices. There is more upward rigidity. But if the firms increase prices, they end up in the new Bertrand equilibrium.

4.5 Equilibrium policy choice

Comparing the firms' total profits in each case, we can derive the equilibrium choices of whether or not to offer the mfc policy. This completes the derivation of the subgame-perfect Nash equilibrium. In the above, we have treated the cost change at the beginning of the second period as unexpected for simplicity. Alternatively, this can be interpreted as firms maximizing profits based on the expected second-period marginal cost, which equals first-period marginal cost c. Evidently, firms may anticipate the possibility of cost changes. They might wish to accommodate their first-period behavior to possible second-period developments. For example, we have shown that for $M = (1, 1)$ firms will always decrease prices if $\Delta c < 0$, incurring the costs of the rebate to first-period consumers. One can imagine firms to take this possibility into account when deciding whether or not to offer the mfc policy, or when setting the first-period price. Therefore we now assume that the firms know the ex ante probability distribution of the cost change.

Let us assume the following probability distribution for the cost change Δc:

$$\Pr\{\Delta c = x\} = \begin{cases} \rho & \text{for } x = \delta \\ \rho & \text{for } x = -\delta \\ 1-2\rho & \text{for } x = 0 \end{cases} \tag{12}$$

where $0 \leq \rho \leq \frac{1}{2}$. That is, there will be a cost change of size δ with probability $0 \leq 2\rho \leq 1$. The change is equally likely to be an increase or a decrease. First, we shortly consider the effects of this probability distribution on the first-period equilibrium prices for each of the three cases M. We will show that it does not affect the results derived above. Then, we turn to the equilibrium policy choice.

For $M = (0,0)$, the two periods of the competition subgame are independent and it is evident that first-period equilibrium prices are not affected by this setup. Second-period equilibrium prices are the Bertrand prices corresponding to the new cost level. It does not matter whether the firms know the probability distribution of the cost change or not.

For $M = (1,0)$, firm A realizes that firm B will behave as a follower in stage 2 for the actual cost level prevailing. Without a cost change, firm A's second-period profits are given by Π_2^A with p^B replaced by the standard reaction function from (2). This can be written as

$$\Pi_2^A(c) = \frac{1}{2b\left(\theta^2-1\right)}\left(p^A - c\right)\left(2p^A - \theta^2 p^A + \theta a + \theta^2 a - 2a - \theta c\right).$$

If firm A maximizes expected profits based upon the probability distribution of the cost change (12), it would replace this expression by

$$\begin{aligned} & (1-2\rho)\,\Pi_2^A(c) + \rho\Pi_2^A(c+\delta) + \rho\Pi_2^A(c-\delta) \\ = \; & \Pi_2^A(c) + 2\rho\frac{\theta\delta^2}{2b\left(\theta^2-1\right)}. \end{aligned}$$

Note that although profits are lower now, the last term does not involve a strategic variable and thus drops out when taking the first derivative. The reaction curve and the first-period equilibrium price are thus not affected.

Similarly, for $M=(1,1)$, the FOCs $\frac{\partial \Pi^i(c)}{\partial p^i}+q^i=0$ should now be replaced by

$$(1-2\rho)\frac{\partial \Pi^i(c)}{\partial p^i}+\rho\frac{\partial \Pi^i(c+\delta)}{\partial p^i}+\rho\frac{\partial \Pi^i(c-\delta)}{\partial p^i}+q^i=0.$$

Note that the term q^i refers to the first-period quantity and therefore is left unaffected by the probability distribution. Since

$$\frac{\partial \Pi^i(c)}{\partial p^i}=\frac{p_j\theta-\theta a+a+c-2p^i}{b\left(1-\theta^2\right)},$$

we have

$$\rho\frac{\partial \Pi^i(c+\delta)}{\partial p^i}+\rho\frac{\partial \Pi^i(c-\delta)}{\partial p^i}=2\rho\frac{\partial \Pi^i(c)}{\partial p^i}$$

and the FOCs for firms anticipating a cost change according to (12) simplify to the original FOCs that we used above.

Summarizing, if firms take into account that costs may change according to the probability distribution (12), in each case M they will set the same equilibrium prices as derived in previous subsections based on an unexpected cost change. Evidently, this may not be true for asymmetric probability distributions.

Now, consider the policy choice of the firms in stage zero. Note that expected second-period profits for firm i in each case M are given by

$$\begin{aligned}
& E\left(\Pi_2^i(M)\right) \\
= \;& (1-2\rho)\left(p^{i*}(M)-c\right)q^{i*}(M) \\
& +\rho\left(p^{i*}(M)-c-\delta\right)q^{i*}(M)+\rho\left(p^{i*}(M)-c+\delta\right)q^{i*}(M) \\
= \;& \left(p^{i*}(M)-c\right)q^{i*}(M)
\end{aligned}$$

where $p^{i*}(M)$ and $q^{i*}(M)$ refer to firm i's equilibrium price and quantity, respectively. This shows that expected second-period profits are equal to the second-period profits without the possibility of a cost change ($\rho=0$).

Payoffs to firms A and B			
		Firm B	
		$M=0$	$M=1$
Firm A	$M=0$	$\Pi_T^A((0,0))$ $\Pi_T^B((0,0))$	$\Pi_T^A((0,1))$ $\Pi_T^B((0,1))$
	$M=1$	$\Pi_T^A((1,0))$ $\Pi_T^B((1,0))$	$\Pi_T^A((1,1))$ $\Pi_T^B((1,1))$

Table 1: Payoffs to firms A and B for different policy choices.

Table 1 presents the payoffs to the firms of different policy choices, where payoff refers to total profits received by the firm in periods 1 and 2. We denote total profits of firm i in situation M by $\Pi_T^i(M)$. Note that the cases $M=(1,0)$ and $M=(0,1)$ are symmetrical.

For $M=(0,0)$, we have

$$\Pi_T^A((0,0)) = \Pi_T^B((0,0)) = 2(a-c)^2 \frac{1-\theta}{b(1+\theta)(2-\theta)^2}.$$

For $M=(1,0)$, firm A's payoff is

$$\Pi_T^A((1,0)) = 2(a-c)^2 \frac{(1-\theta)(2-\theta)(2+\theta)^3}{b(1+\theta)\left(8-3\theta^2\right)^2},$$

and for firm B total profits are

$$\Pi_T^B((1,0)) = 2(a-c)^2 \frac{(1-\theta)\left(8+4\theta-\theta^2\right)^2}{4b(1+\theta)\left(8-3\theta^2\right)^2}.$$

For $M=(1,1)$, total profits are given by

$$\Pi_T^A((1,1)) = \Pi_T^B((1,1)) = 2(a-c)^2 \frac{2(1-\theta)}{b(1+\theta)(3-2\theta)^2}.$$

In order to determine the subgame-perfect Nash equilibrium, we have to compare the various profit functions. Let us first focus on firm A. If firm B

does not offer the policy, firm A prefers to offer it whenever

$$(2-\theta)^3 (2+\theta)^3 - \left(8-3\theta^2\right)^2 > 0$$

which is satisfied for any $\theta \in (0,1)$. If firm B does offer the policy, firm A prefers to do so as well whenever

$$2\left(4\left(8-3\theta^2\right)^2\right) - (3-2\theta)^2 \left(8+4\theta-\theta^2\right)^2 > 0$$

which is satisfied whenever $\theta > 0.300$. Otherwise, firm A prefers not to offer the policy when firm B does. Because of symmetry, analogous results hold for firm B. This shows that in the subgame-perfect Nash equilibrium, if $\theta > 0.300$, both firms will offer the policy, and if $\theta < 0.300$, one of the firms offers the policy (either firm A or firm B).

Using the results from previous subsections, this implies more downward price rigidity following a cost change for $\theta < 0.300$, but more upward rigidity instead for $\theta > 0.300$. This latter result is surprising since it contradicts the intuition about price changes with an mfc clause that firms are reluctant to decrease prices. Note however that this intuition is based on the unilateral response of a firm to price changes by a competitor, whereas our results refer to the response of *equilibrium* prices to *cost* changes.

4.6 Numerical example

To conclude this section, we present a numerical example to illustrate our results, substituting specific parameter values. For simplicity we focus on the case in which both firms offer an mfc clause (so $\theta > 0.300$) and there is more upward than downward rigidity. Symmetry implies that the price set by firm A equals the price set by firm B. For notational convenience, we therefore omit the superscripts A and B.

First, we analyze the general implications of a cost change for this case of our simple model in more detail. Initially, the marginal cost is at level c and the equilibrium price is given by p^*, defined by (10). After a cost decrease, the new equilibrium price will be p^* with c replaced by the new marginal cost $\underline{c} < c$. From (10), p^* can be written as

$$p^* = \frac{2(1-\theta)}{3-2\theta}a + \frac{1}{3-2\theta}c.$$

The price decrease will thus be $\Delta p = \frac{1}{3-2\theta}\Delta c$, where $\Delta c = \underline{c} - c$. Note that $\Delta p < \Delta c$, so prices are somewhat rigid downward. After a cost increase, the new equilibrium price will be $\widetilde{p}$ defined by (3), with c replaced by the new marginal cost $\overline{c} > c$, if this price $\widetilde{p}(\overline{c})$ exceeds the critical value $\overline{p}$. If this is not the case, the price remains at the initial level p^*. Note that now we have to recalculate the critical value $\overline{p}$ for the new cost level $\overline{c}$. We cannot simply substitute for c in the definition of $\overline{p}$ in (11), because after a cost increase $\overline{p}(\overline{c})$ is determined by the intersection of the new standard reaction function and the *old* (first-period) equilibrium price. This gives

$$\overline{p}(\overline{c}) = c + \frac{(1+2\theta)(1-\theta)}{(3-2\theta)\theta}(a-c) - \frac{\overline{c}-c}{\theta}.$$

The condition $\widetilde{p}(\overline{c}) > \overline{p}(\overline{c})$ simplifies to

$$\overline{c} - c > \frac{(1-\theta)(a-c)}{3-2\theta} \equiv \widehat{\delta}.$$

If this condition is satisfied and the cost increase exceeds the critical level $\widehat{\delta}$, the price increase will be

$$\Delta p = \widetilde{p}(\overline{c}) - p^* = \frac{1}{2-\theta}\Delta c + \frac{\theta - 1}{(2-\theta)(3-2\theta)}(a-c),$$

where $\Delta c = \overline{c} - c$. It can be shown that this expression is smaller than $\frac{1}{3-2\theta}\Delta c$ for any $\theta \in (0,1)$ and $\Delta c < a - c$. This shows that for the case $M = (1,1)$ the relative price adjustment $\frac{\Delta p}{\Delta c}$ is *always* smaller for a cost increase than for a corresponding decrease, even if the cost increase is large enough for the price to rise. So although prices are somewhat rigid downward, there is more upward rigidity.

	c	$\theta = 0.7$, $a = 130$, $\widehat{\delta} = 5.625$: p	$\frac{\Delta p}{\Delta c}$	$\theta = 0.7$, $a = 150$, $\widehat{\delta} = 9.375$: p	$\frac{\Delta p}{\Delta c}$	$\theta = 0.9$, $a = 130$, $\widehat{\delta} = 2.500$: p	$\frac{\Delta p}{\Delta c}$
PERIOD 1	100	111.250		118.750		105.000	
PERIOD 2							
decrease	98	110.000	0.625	117.500	0.625	103.333	0.833
	96	108.750	0.625	116.250	0.625	101.667	0.833
	94	107.500	0.625	115.000	0.625	100.000	0.833
	92	106.250	0.625	113.750	0.625	98.333	0.833
	90	105.555	0.625	112.500	0.625	96.667	0.833
increase	102	111.250	0	118.750	0	105.000	0
	104	111.250	0	118.750	0	106.364	0.341
	106	111.539	0.048	118.750	0	108.182	0.530
	108	113.077	0.228	118.750	0	110.000	0.625
	110	114.615	0.337	119.231	0.048	111.818	0.682

Table 2: Numerical example. c refers to the different cost levels, and p refers to the resulting equilibrium prices.

Using these results, we can present the numerical example. In Table 2, we start with the case in which $\theta = 0.7$ and $a = 130$. We present the critical value $\widehat{\delta}$, and the initial equilibrium price for the cost level $c = 100$. This is the price charged by the firms in the first period. Then, we present the second-period equilibrium price as well as the relative price adjustment $\frac{\Delta p}{\Delta c}$ for several cost decreases and cost increases. The cost changes are multiples of 2 and range from $|\Delta c| = 2$ to $|\Delta c| = 10$. In order to illustrate the effects of different values of θ and a, we continue by presenting the results for $\theta = 0.7$

and $a = 150$, and for $\theta = 0.9$ and $a = 130$.

The table shows that the asymmetry in price adjustments predicted by the model may be quite serious. For the case with $\theta = 0.7$ and $a = 150$, the price will not be adjusted for a cost increase up to $\widehat{\delta} = 9.375$ percent! And even if the price rises, the relative price increase $\frac{\Delta p}{\Delta c}$ is quite small (even below 0.1 for some cases). Also, the table illustrates that for a given set of parameters the relative price adjustment $\frac{\Delta p}{\Delta c}$ is *always* larger (in absolute value) for a cost decrease than for a cost increase of the same size, even if the cost increase is large enough for the price to adjust. Further, for a cost decrease the size of $\frac{\Delta p}{\Delta c}$ depends on θ only, whereas for a cost increase it depends on a and Δc as well.

The kind of behavior described by Table 2 can be tested empirically. For example, we could test whether prices do not respond to small cost increases or whether they respond more to cost decreases than to cost increases of the same size. In general, there exist many empirical studies that test for the presence of such asymmetries in price adjustments (some of which are mentioned in section 1). However, these studies do not consider the particular case of firms that offer the mfc clause. On the other hand, there are some empirical studies of the effects of the mfc clause on prices (e.g. Scott Morton, 1997, and Crocker and Lyon, 1994), but these are not analyzing in particular the effect of cost changes. They focus on testing whether the clause itself results in higher prices, as predicted by Cooper (1986).

5 Concluding remarks

We argued that in a model of price competition with a most-favored-customer clause there are asymmetric price adjustments following a cost change. Depending on the parameters of the model, there may be either more downward or more upward price rigidity. In a duopoly, if both firms decide to offer the policy, there is always more upward rigidity. This finding of upward rigidity with a most-favored-customer clause is surprising since one would expect firms to be reluctant to *decrease* price because of the cost of rebates.

The intuition behind this result is related to the fact that the equilibrium price changes we refer to in the above are cost-change induced. They are not unilateral responses to price changes by the competitor. Indeed, if costs do not change but a competitor reduces its price for some reason, a firm offering the clause will unilaterally choose to keep its price constant because of the cost of rebates otherwise incurred (if the price reduction by the competitor is not too large). This is reflected in the shape of the reaction curves. However, equilibrium prices are determined by the interaction of the two firms' price-setting behavior. That is, they are determined by the intersection of the reaction curves of the two firms. If costs change these reaction curves shift. So the response of equilibrium prices to a cost change is described by the difference between the intersections of the old reaction curves and the new reaction curves, respectively. Even if a firm is unilaterally reluctant to decrease its price when the other firm does so, this does not necessarily imply that prices are more rigid downward after a cost change.

We illustrate our argument with a simple linear model of a price setting duopoly with heterogeneous goods. In the equilibrium, either one firm offers the policy, or both offer it. For relatively homogeneous goods, both firms offer the policy and there is more upward rigidity. For strongly differentiated goods, one firm offers the policy and there is more downward rigidity. When only one firm offers the policy in a model with a different functional form, however, there may alternatively be more upward rigidity. Again this depends on the parameters of the model. Finally, we presented a numerical example to show that the predicted asymmetry in price adjustments may be substantial. This paper thus gives a new explanation for asymmetry in price adjustments, where the asymmetry may refer to either more upward or more downward price rigidity.

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